Degradability of Cell-Wall Constituents in Corn Internodes During Stalk Development

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Introduction

Cell-wall concentration in forage dry matter and its degradability greatly influence availability of forages to livestock that consume it. Because forage crops represent the major feed resource for cattle, improvement in dry matter digestibility and wall degradability are primary goals of many research programs. Polymerized cell-wall lignin and associated hydroxycinnamic acids [primarily ferulic acid (FA) and *p*-coumaric acid (PCA) in grass species], laid down during plant development, are thought to be the primary limiters to microbial degradation of wall polysaccharides by ruminants. The manner in which lignin and hydroxycinnamic acids limit degradability of walls is not fully understood. In some studies lignin composition and presence of hydroxycinnamic acids in the wall were more closely related to wall degradability than was lignin concentration. Cross linkage of lignin with feruloylarabinoxylan polysaccharides in the wall by FA may play a major role in explaining how lignification limits wall degradability in grasses.

During corn stalk growth, individual internodes develop sequentially at different rates. Within a growing internode the younger, undifferentiated tissues are near the intercalary meristem at the base of the internode and become progressively more developed higher up the internode. Progressive incorporation of hydroxycinnamic esters, especially FA during primary wall formation, is thought to be a key activity allowing lignin to limit wall degradability. During internode cell-wall development, polysaccharides, uronic acids, and hydroxycinnamic acids are deposited in a sequential fashion through the middle lamella, primary, and secondary walls. As lignification is initiated, beginning in the middle lamella and threading through the primary and secondary walls, the earlier-formed cell-wall constituents are bound by randomly invading lignin polymers that cross-link via existing FA and PCA ester and ether bonds. This study was conducted to determine the progressive resistance to degradation by differentiating tissues in walls of corn internodes.

Materials and Methods

Growth chamber grown corn at the 15th leaf stage was harvested and Internodes 7 (I7) through 13 (I13) were excised. Internode 6 was the first aboveground internode. Each internode was divided into lower and upper halves, and the outer rind (including cuticle and vascular strands) was separated from the central pith tissue. The pith tissue was comprised mostly of parenchymatous cell types and randomly distributed vascular strands. Ground internode samples were fermented in vitro for 24 and 96 h to provide estimates of the rapidly degradable and potentially degradable fractions, respectively. Neutral sugar residues before and after fermentations were determined by LC after acid hydrolysis of the starch-free, alcohol-insoluble residue. Total uronic acids were estimated colorimetrically using galacturonic acid as the calibration standard. The experiment was in a randomized complete block design with two replicates. Data are presented averaged over location (lower vs. upper) within internode.

Results and Discussion

When harvested I12 and I13 were undergoing rapid cellular elongation in the lower sections, and differentiation and initiation of lignification in upper sections; I11 was still elongating in the lower third of the internode, but had ceased elongation and begun differentiation and lignification in the upper two-thirds of the internode; and I7 through I10 were fully elongated and actively engaged in secondary cell-wall thickening. Degradability of wall polysaccharides declined markedly from the

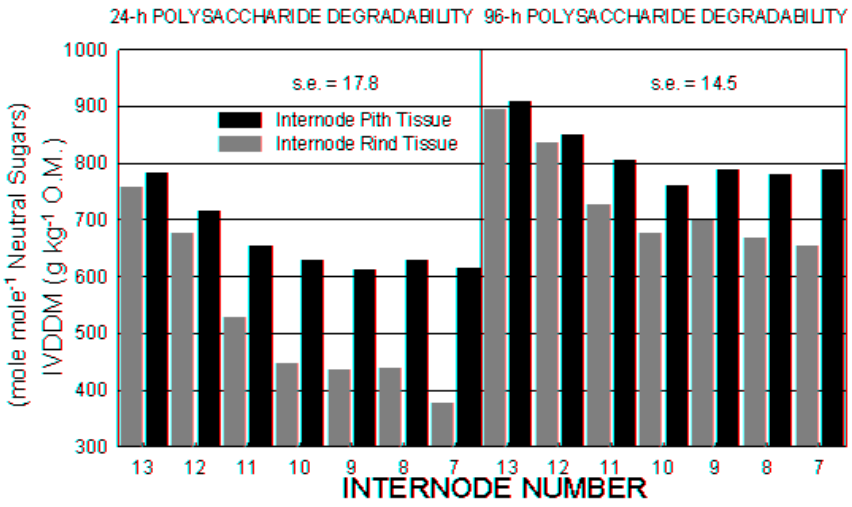

Figure 1. Polysaccharide degradability of pith and rind tissue from internodes of corn after 24- and 96-h incubation in rumen fluid.

youngest internode (I13) through I11 and then leveled off or declined more slowly through the remaining internodes, especially in the pith tissue (Fig.1). During both fermentation times, pith of the younger internodes (I13 to I11) degraded more quickly and extensively than rind; differences in degradability between pith and rind widened with increasing internode maturity. Potentially degradable (96 h) polysaccharide in both pith and rind of I13 was near 90% and remained above 75% in the pith of older internodes, whereas the rind tissue of older internodes degraded only 67%.

Examining the digestibility of the neutral sugars and uronic acids which are the building blocks of wall polysaccarides improves understanding of the manner in which structural carbohydrates interact to limit their digestibility. A substantial increase in degradability occurred between 24 and 96 h for glucose and xylose, with smaller increases in degradability for arabinose, uronic acids and galactose (Table 1). Most of the mannose was degraded by 24 h.

Conclusions

Resistance to digestion increases as soon as lignin polymerization is initiated. It is likely that condensed phenolics in the middle lamella and primary wall of even I13 increase resistance to degradability early in the lignification process. This early resistance is thought to occur from feruloyl-ester cross links between arabinoxylan and the lignin. Degradability remained high in fully differentiated cells of corn pith parenchyma and collenchyma that have secondary wall thickening.